CHAPTER THREE

Transportation and Safety

Transportation-related injuries and deaths are a major public health problem in the United States. Over the past decade, transportation crashes have been responsible for approximately half of all accidental deaths in this country (see table 3-1). highway vehicle crashes are the leading cause of death of Americans between the ages of 15 and 24, and accounted for 93 percent of all transportation-related deaths in 1994. They are also responsible for as many pre-retirement years of life lost as cancer and heart disease, about 1.2 million years annually (see figure 3-1). This reflects the relative youth of crash victims. Nonfatal injuries from highway crashes are a major problem as well. These injuries are the second largest category of both hospitalized and nonhospitalized injuries.

Inadequate data and inconsistent measures of accident risk across modes complicate efforts to formulate strategies to reduce transportation risks.

Despite the progress made in the past two decades in transportation safety, millions of people are still injured and tens of thousands of people are killed in transportation crashes each year. Thus, much work remains to be done to develop a better understanding of the causes of crashes and to prevent them. In particular, we need to better understand the human factors that cause or facilitate crashes. Examples include operator impairment because of substance abuse, medical conditions, or human fatigue, and the operator's interaction with new technologies used both inside and outside the vehicle. Understanding the role of human

TABLE 3-1: ACCIDENTAL DEATHS, 1981–94

Year	All causes	Transportation related	Transportation related (percent)
1981	100,704	51,335	51.0%
1985	93,457	46,400	49.6
1990	91,983	47,269	51.4
1994	92,200P	43,322	47.0

NOTE: Deaths reported in the "All causes" column generally occurred within one year of an accident or crash; deaths reported in the "transportation related" column generally occurred within 30 days of an accident or crash. Hence, the percentage column may understate the proportion of transportation-related deaths.

KEY: P = preliminary.

SOURCES: All causes—National Safety Council, *Accident Facts,* 1995 Ed. (Itasca, IL: 1995). Transportation related—various sources, as compiled and cited in U.S. Department of Transportation, Bureau of Transportation Statistics, *National Transportation Statistics 1996* (Washington, DC: November 1995).

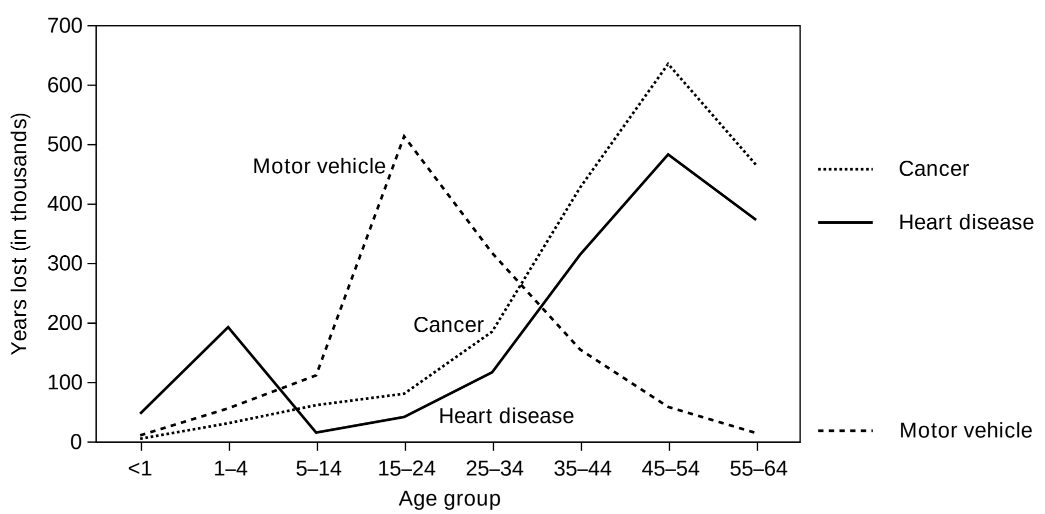
factors is one of the most pressing tasks facing the transportation safety community today.

This chapter summarizes recent transportation safety trends, including the number and nature of transportation accidents, injuries, and fatalities. It also examines human factors affecting accidents and addresses two areas of particular concern, commuter airline safety and accidents at highway-rail crossings. The chapter also discusses technological concepts now under development that have the potential to improve transportation safety. Finally, data needs in transportation safety research are examined.

Trends in Transportation Safety

There are many ways to analyze accident, injury, fatality, and cost trend data. One often used approach is to examine annual totals. Annual totals, however, do not take into account the evolving nature of the transportation system and, in particular, changes in *exposure to risk.* Therefore, to increase the comparability and usefulness of accident statistics over time and across modes, measures that account for variations in risk exposure must be used.

FIGURE 3-1: PRE-RETIREMENT YEARS OF LIFE LOST BY AGE, 1992



SOURCE: Calculated based on a method and data in U.S. Department of Health and Human Services, *Health, United States, 1994,* DHHS Pub. No. (PHS) 95-1232 (Hyattsville, MD: 1995).

Risk exposure means that the more an individual uses the transportation system, the more that person is at risk of involvement in a transportation-related crash. Risk exposure can be expressed in many ways, and the "best" measure may vary according to the mode under examination and the kind of analysis performed.

Indeed, as our transportation system grows, more people will be exposed to risk, and more accidents can be expected to occur, barring changes in behavior or advances in safety technology. Therefore, it is instructive to examine the number of crashes in a way that acknowledges changes in risk exposure. Accident rates are a measure of incidents per unit of risk exposure, and can take several forms: injury costs per number of vehicle-miles traveled, fatalities or injuries per number of hours of operation, fatalities per unit distance of travel, injuries and/or accidents per number of registered vehicles, and fatalities per number of person-miles traveled.

Fatalities, Injuries, and Accidents

More than 6.5 million transportation accidents or incidents occurred in 1994, a 6.4 percent increase from 1993, and an 8.3 percent increase from 1992 (see table 3-2). These accidents were responsible for more than 3 million injuries and over 43,000 fatalities (see tables 3-3 and 3-4.)

By all measures, accident statistics are dominated by motor vehicle accidents. During the past two decades, motor vehicle accidents accounted for 90 to 93 percent of all transportation fatalities and an even larger percentage of

TABLE 3-2: ACCIDENTS/INCIDENTS[a] BY TRANSPORTATION MODE, 1985–94

Year	Air carrier[b]	Commuter air[c] and air taxi[d]	General aviation[e]	Motor vehicle[f]	Railroad[g]	Rail-highway grade crossings[h]	Rail rapid transit[i]	Waterborne transport	Recreational boating	Gas and liquid pipelines
1985	22	173	2,738	—	3,275	6,919**R**	—	3,439	6,237	514
1990	24	123	2,216**R**	6,471,000[j]	2,879	5,713	12,178**R**	3,613	6,411	379
1991	26	110	2,177**R**	6,117,000	2,658**R**	5,386	14,102	2,222	6,573	450**R**
1992	18	99	2,075**R**	6,000,000	2,359**R**	4,910	15,512	3,297	6,048**R**	388**R**
1993	23	87	2,042**R**	6,105,000	2,611**R**	4,892	15,082**R**	2,654**R**	6,335	447**R**
1994**P**	22	94	1,989	6,492,000	2,504	4,979	15,258	2,833	6,906	466

[a] Rail rapid transit incidents are collisions, derailments, personal casualties, fires, and property damage in excess of $1,000 associated with transit agency revenue vehicles; all other facilities on the transit property; and service vehicles, maintenance areas, and rights-of-way. Hazardous materials incidents are reported separately in chapter 7, table 7-9.
[b] Large carriers operating under 14 CFR 121, all scheduled and nonscheduled service.
[c] All scheduled service operating under 14 CFR 135 (commuter air carriers).
[d] Nonscheduled service operating under 14 CFR 135 (on-demand air taxis).
[e] All operations other than those operating under 14 CFR 121 and 14 CFR 135.
[f] Includes only police-reported crashes.
[g] Train accidents only.
[h] Motor vehicle accidents at grade crossings are also counted in the motor vehicle column.
[i] Reporting criteria and source of data changed between 1989 and 1990; beginning in 1990, accidents/incidents include those occurring throughout the transit station (e.g., stairways), including injuries to nonpatrons. Reporting level for property damage was lowered, and property damage only accidents were reported for the first time.
[j] National Safety Council procedures for estimating the number of accidents were changed in 1989. Thus, the data shown are not comparable to earlier years.

KEY: **R** = revised; **P** = preliminary.

SOURCES: Various sources, as compiled and cited in U.S. Department of Transportation, Bureau of Transportation Statistics, *National Transportation Statistics 1996* (Washington, DC: November 1995).

TABLE 3-3: INJURIES BY TRANSPORTATION MODE, 1985–94

Year	Air carrier[a]	Commuter air[b] and air taxi[c]	General aviation[d]	Motor vehicle[e]	Railroad	Rail-highway grade crossings[f]	Rail rapid transit[g]	Waterborne transport	Recreational boating	Gas and liquid pipelines
1985	30	59	517	—	31,617	2,687	—	172	2,757	126**R**
1990	39	47	391	3,231,000	22,736	2,407	10,036	175	3,822	76**R**
1991	26	57	420	3,097,000	21,374	2,094	9,285	110	3,967	98**R**
1992	13	24	418	3,070,000	19,408	1,975	10,446	172	3,683	118**R**
1993	16**R**	26	386**R**	3,125,000	17,284	1,837	10,532**R**	133**R**	3,559	112**R**
1994**P**	35	38	452	3,215,000	14,850	1,961	11,170	146	4,084	1,970[h]

[a] Large carriers operating under 14 CFR 121, all scheduled and nonscheduled service.
[b] All scheduled service operating under 14 CFR 135 (commuter air carriers).
[c] Nonscheduled service operating under 14 CFR 135 (on-demand air taxis).
[d] All operations other than those operating under 14 CFR 121 and 14 CFR 135.
[e] Injuries from police-reported crashes only. Procedures for estimating injuries were changed in 1989. Thus, data shown are not comparable to prior years.
[f] Motor vehicle injuries at grade crossings are also counted in the motor vehicle column.
[g] Reporting criteria and source of data changed between 1989 and 1990. Beginning in 1990, injury data includes those occurring throughout the transit station (e.g., stairways), and including injuries to nonpatrons.
[h] Includes 1,851 injuries from two flood-related incidents involving two oil pipelines. The large number of reported injuries reflects the widespread distribution of the oil by the flood waters.

KEY: **R** = revised; **P** = preliminary.

SOURCES: Various sources, as compiled and cited in U.S. Department of Transportation, Bureau of Transportation Statistics, *National Transportation Statistics 1996* (Washington, DC: November 1995).

transportation accidents and injuries (see tables 3-2, 3-3, and 3-4). According to 1992 data, motor vehicle accidents are the leading cause of accidental death for people under the age of 75. (National Safety Council 1995)

The number of motor vehicle fatalities has declined significantly from the historic high of 54,589 fatalities in 1972. In 1992, the number of highway fatalities was 39,250 (table 3-4), the lowest number of fatalities since the early 1960s. The number of fatalities, however, grew in 1993 and 1994. Preliminary data indicate there were 41,700 fatalities involving highway vehicles in 1995. (USDOT NHTSA 1996) In spite of the recent increases in the number of deaths, the fatality rate per 100 million vehicle-miles traveled reached its lowest recorded level in 1994 (see figure 3-2 and table 3-5), where it remained in 1995.

Serious injuries, especially those resulting from highway accidents, are a major problem. Severe injuries (those in which the victim is incapacitated) outnumber traffic deaths by 10 to 1. After declining in the 1985 through 1992 period, the total number of injuries increased in 1993 and 1994 (see table 3-3). Injury statistics are underreported. Many highway crashes resulting in a minor injury are not reported to the police. Furthermore, of the crashes reported to the police, only slightly more than 80 percent of the injuries are identified. Police often find it difficult to determine injury severity. Considering the underreporting of both crashes and injuries, police accident reports capture only 82 percent of hospitalized crash victims and 55 percent of injured people not requiring hospital care. (Miller 1995)

Both the number of fatalities and injuries, and their rate of occurrence, will merit close monitoring in the years ahead. The increase in the number of motor vehicle deaths and injuries, while troubling, occurred at the same time that the fatality rate reached its lowest level ever in terms of vehicle-miles traveled. Whether the

TABLE 3-4: FATALITIES BY TRANSPORTATION MODE, 1960–94

Year	Air carrier[a]	Commuter air[b] and air taxi[c]	General aviation[d]	Motor vehicle	Railroad[e]	Rail-highway grade crossings[f]	Rail rapid transit[g]	Waterborne transport[h]	Recreational boating	Gas and liquid pipelines
1960	499	—	787	36,399	924	—	—	—	819	—
1965	261	—	1,029	47,089	923	—	—	—	1,360	—
1970	146	100	1,310	52,627	785	—	—	178	1,418	26
1975	122	97	1,252	44,525	575	917**R**	—	243	1,466	21
1980	1	142	1,239	51,091	584	833	83	206	1,360	19**R**
1985	526	113	955	43,825	454	582	17	131	1,116	31
1990	39	56	766	44,599	599	698	117	85	865	9**R**
1991	50	150	785**R**	41,508	586	608	103	30	924	14
1992	33	91	860**R**	39,250	591	579	91	105	816	15**R**
1993	1	66	737**R**	40,150	653	626	83**R**	95**R**	800	17**R**
1994**P**	239	89	706	40,676	611	615	76	52	784	22

[a] Large carriers operating under 14 CFR 121, all scheduled and nonscheduled service.
[b] All scheduled service operating under 14 CFR 135 (commuter air carriers).
[c] Nonscheduled service operating under 14 CFR 135 (on-demand air taxis).
[d] All operations other than those operating under 14 CFR 121 and 14 CFR 135.
[e] Includes fatalities resulting from train and nontrain accidents.
[f] Includes pedestrian fatalities not otherwise counted. Motor vehicle fatalities at grade crossings are also counted in the motor vehicle column.
[g] Reporting criteria and source of data changed between 1989 and 1990. Starting in 1990, fatality figures include those occurring throughout the transit station, including nonpatrons.
[h] Vessel casualties only.

KEY: **R** = revised; **P** = preliminary.

SOURCES: Motor vehicles—historical data provided by U.S. Department of Transportation, National Highway Traffic Safety Administration. All other modes—various sources, as compiled and cited in U.S. Department of Transportation, Bureau of Transportation Statistics, *National Transportation Statistics 1996* (Washington, DC: November 1995).

fatality rate will continue to decline will depend on many factors, as discussed below. Highway travel will inevitably increase in the future, however, thereby increasing accident risk, all else being equal.

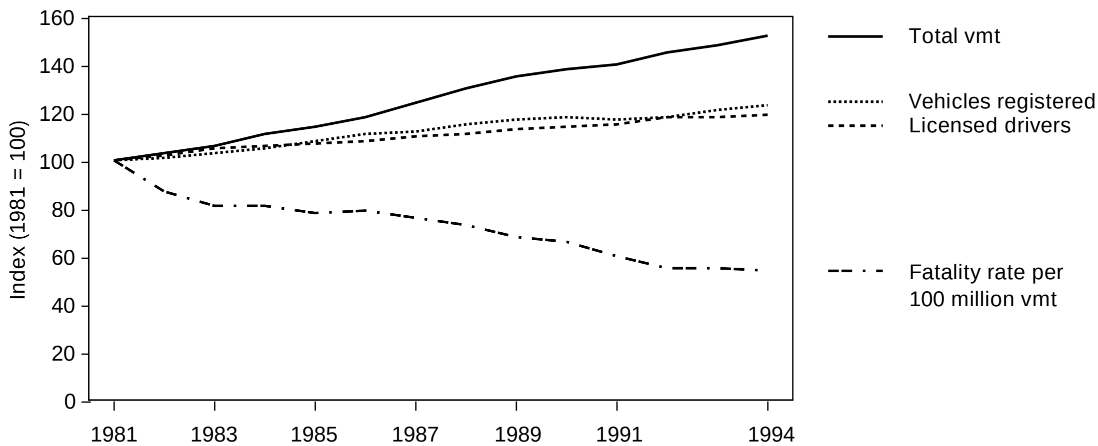
A complicating factor for future analysis will be the greater variation among the states in speed limit and other policies relevant to safety. Congress, in the 1995 National Highway System Designation Act, authorized states to set their own policies about speed limits and about whether to require motorcyclists to wear helmets. How the states respond will be an important highway safety issue in the coming years.

► Costs of Transportation Crashes

The personal, social, and economic costs of transportation accidents include pain and suffering, direct costs sustained by injured people and their insurers, and, for many crash victims, a lower standard of living or quality of life. The taxpayer and society may be burdened by health care costs not paid by individuals or insurers, lost productivity and associated loss of tax revenues, and public assistance for injured people.

The total economic costs to U.S. society over the lifetime of people killed or injured in 1990 transportation crashes is estimated at over $135 billion. (USDOT NHTSA 1993) This includes

FIGURE 3-2: INDICATORS OF MOTOR VEHICLE USE AND FATALITY RATE, 1981–94



KEY: vmt = vehicle-miles traveled.

SOURCES: Fatality rate—U.S. Department of Transportation, *National Transportation Statistics 1996* (Washington, DC: November 1995). Total vmt, vehicles registered, licensed drivers—U.S. Department of Transportation, Federal Highway Administration, *Highway Statistics 1994,* FHWA-PL-95-042 (Washington, DC: October 1995).

TABLE 3-5: FATALITY RATES BY TRANSPORTATION MODE, 1960–94

Year	U.S. air carrier (per 100 million miles flown)	General aviation (per 100,000 hours flown)	Motor vehicle (per 100 million vehicle-miles)	Railroad (per million train-miles) [a]	Recreational boating (per 100,000 numbered boats) [b]
1960	0.864	6.49	5.06	—	32.8
1965	0.329	6.54	5.30	—	21.3
1970	0.002	5.04	4.74	0.94	19.2
1975	0.069	4.35	3.36	0.76	20.1
1980	0.000	3.40	3.35	0.81	15.8
1985	0.073	3.37	2.47	0.80	11.6
1990	0.009	2.69 **R**	2.08	0.98	7.8
1991	0.011 [c]	2.88 **R**	1.91	1.02	8.3
1992	0.007	3.61 **R**	1.75	1.00	7.3
1993	0.000 [d]	3.28	1.75	1.06	7.1
1994	0.046	3.36 **P**	1.73	0.93	6.9

[a] Calculated as total railroad fatalities (from train accidents, train incidents, and nontrain incidents) per million train-miles.
[b] The Coast Guard changed its methodology for calculating the number of boats in 1994. The numbers have been updated from 1975 to 1994. The figures cited here represent numbered boats.
[c] Does not include 12 persons killed on a commuter aircraft that collided with an airliner.
[d] Figure does not reflect one fatality.

KEY: **R** = revised; **P** = preliminary.

SOURCES: Motor vehicles—U.S. Department of Transportation, National Highway Traffic Safety Administration. All other modes—various sources, as compiled and cited in U.S. Department of Transportation, Bureau of Transportation Statistics, *National Transportation Statistics 1996* (Washington, DC: November 1995).

more than $14 billion in health care expenditures, $35.6 billion in property damage costs, and nearly $40 billion in market productivity losses. Taxpayers will pay $11.4 billion of the total cost of crashes to cover publicly funded health care expenses, reductions in income tax revenues, and increases in public assistance expenses. (USDOT NHTSA 1993) The above estimate does not include the value of *lost quality of life*. If this valuation is included, the cost measure is called the *comprehensive injury cost.* There is considerable uncertainty about how to express such broader costs in monetary terms. According to a preliminary estimate by one research group, the comprehensive injury costs for motor vehicle crashes in 1988 were more than twice the lifetime monetary cost of motor vehicle injuries, fatalities, and property damage. (Miller 1995) The omission of the cost of lost quality of life can result in underestimating the benefits of investments to make travel safer.

Modal Comparison

Assessing the relative safety of transportation modes is necessary for informed research, development, and investment decisions. Modes, however, differ in their functions, risk exposures, and other characteristics; thus, modal comparisons should be made with caution.

Fatality rate is one method for comparing transportation safety among modes (see table 3-5.) Although a lack of common measures impedes analysis, in general, fatality rate trends show that commercial air and rail continue to be the two safest modes. The rates for highway vehicles (which include vehicles as different in their safety profiles as buses and motorcycles), general aviation, and recreational boating are much higher, but these modes have become much safer over the past two decades. The risk associated with motorcycles is striking: on a per-vehicle-mile basis motorcycle riders are over 15 times more likely to be involved in fatal crashes than occupants of either passenger cars or trucks (see table 3-6).

Despite the continued increases in the number of vehicles, the number of drivers, and the amount of driving, the 1994 fatality rate for all highway vehicles was 1.73 per 100 million miles driven, the lowest ever recorded (see table 3-5 and figure 3-2). The improvement in highway safety can be attributed to several factors, including better designed, safer highways, increased use of seat belts, increased market penetration of air bags and other safety equipment, aggressive anti-drunk-driving programs, and lower vehicle occupancy rates.

Similarly, the boating fatality rate decreased despite an increase in registered boats. Nearly all deaths in boating accidents were drownings, and 75 percent of these deaths could have been prevented if boaters had worn life jackets or other floatation devices. (USDOT Coast Guard 1995)

International Comparison of Transportation Fatalities

Transportation safety is a major public health concern, not just in the United States, but in other highly motorized Organization for Economic Cooperation and Development (OECD) countries. Among the seven major OECD countries (the G-7 countries), the United States, with its large and highly mobile population, has the greatest number of transportation fatalities. However, its fatality rate is one of the lowest when vehicle-miles driven is considered. (USDOT BTS 1994) Furthermore, statistics indicate that motor vehicle accidents in the United States tend to be less severe than those in the other G-7 countries: the fatality rate in the United States is 13 deaths per 1,000 casualties (see table 3-7). Accidents are most severe in France, which has a fatality rate almost four times as high as that of the United States. Thus,

Table 3-6: U.S. Motor Vehicle Fatalities, 1975–94

	Passenger car occupants		Light-truck occupants		Large-truck occupants		Motorcyclists			
Year	Fatalities	Fatality rate [a]	Fatalities	Fatality rate [a]	Fatalities	Fatality rate [a]	Fatalities	Fatality rate [a]	Pedestrian fatalities	Total nonoccupant [b] fatalities
1975	25,928	2.5	4,856	2.4	961	1.2	3,189	56.7	7,516	8,600
1980	27,449	2.5	7,486	2.5	1,262	1.2	5,144	50.4	8,070	9,164
1985	23,212	1.9	6,889	1.7	977	0.8	4,564	50.2	6,808	7,782
1990	24,092	1.7	8,601	1.6	705	0.5	3,244	33.9	6,482	7,465
1991	22,385	1.6	8,391	1.4	661	0.4	2,806	30.6	5,801	6,768
1992	21,387	1.5	8,096	1.3	585	0.4	2,395	25.1	5,549	6,370
1993 **R**	21,566	1.5 [c]	8,511	1.3	605	0.4	2,449	24.8	5,649	6,576
1994 **R**	21,997	1.5	8,904	1.3	670	0.4	2,320	22.6	5,489	6,398

[a] Calculated as fatalities per 100 million vehicle-miles traveled.
[b] Includes pedestrian, pedalcyclist, and other nonoccupant fatalities.
[c] Some minivans and sport-utility vehicles that were previously classified as passenger cars are classified as trucks.

KEY: **R** = revised.

NOTE: Excludes buses. Passenger car and light-truck occupant fatality rates reflect National Highway Traffic Safety Administration revisions. In some instances, data may differ from previously published figures.

SOURCE: U.S. Department of Transportation, National Highway Traffic Safety Administration (NHTSA), *Traffic Safety Facts 1994,* DOT HS 808 292 (Washington, DC: August 1995). Revised data for 1994 provided by NHTSA.

Table 3-7: Accident Severity by Road-User Category, 1992
(number of fatalities per 1,000 casualties)

Country	Drivers	In-vehicle passengers	Pedestrians	On bicycles	On mopeds	On motorcycles	Other[a]	Total
United States[b]	10	10	62	12	—	42	14	13
Canada[b]	13	12	34	9	—	26	38	15
Japan	13	13	48	12	12	29	47	17
France	55	43	52	51	25	51	50	48
Germany[b]	22	20	40	13	15	25	20	22
Italy[b]	28	25	51	55	22	31	48	31
Great Britain	11	10	26	8	5	19	11	14

[a] Other includes in commercial vehicles, buses and coaches, and on horse.
[b] 1991 data are used.

SOURCE: European Conference on Ministers of Transport, *Statistical Report on Road Accidents in 1992* (Paris, France: 1994), table 6, p. 47.

in terms of fatalities per distance driven and fatalities per number of injuries, the United States has one of the safest transportation systems in the world. Comparing safety statistics among various countries is, however, complicated by inconsistencies in definitions and reporting criteria, particularly for motor vehicle injuries.

Human Factors

Lapses in operator performance contribute to a significant number of fatalities and injuries in all modes of transportation. Such lapses are responsible for one-third of all railroad accidents and are the number one cause cited in aviation accidents. Operator error is also probably the single-most important factor in truck and bus accidents.

Analysis of police reports suggests that approximately 85 percent of the factors contributing to motor vehicle crashes were associated with the driver, 10 percent involved the highway, and 5 percent involved the vehicle. (Evans 1991) Two other studies have obtained similar results. A U.S. study found that road users are identified as the sole factor in 57 percent of crashes, the road environment in 3 percent, and the vehicle in 2 percent. (Evans 1991) The interaction between the road environment and road users contributes to 27 percent of crashes, and the interaction between road users and vehicles contributes to 6 percent. Results from a United Kingdom study are remarkably consistent. (Evans 1991) The importance of human factors in causing transportation accidents is unquestioned.

The study of human factors in transportation safety is extremely complex and must take many factors into account. These include the operator's risk-taking propensity and risk perception, and the operator's interaction with technology (including the vehicle) and the surrounding environment. Operator impairment (poor driving performance because of alcohol, drugs, medical conditions, aging, fatigue, or any combination of these factors) also must be taken into account.

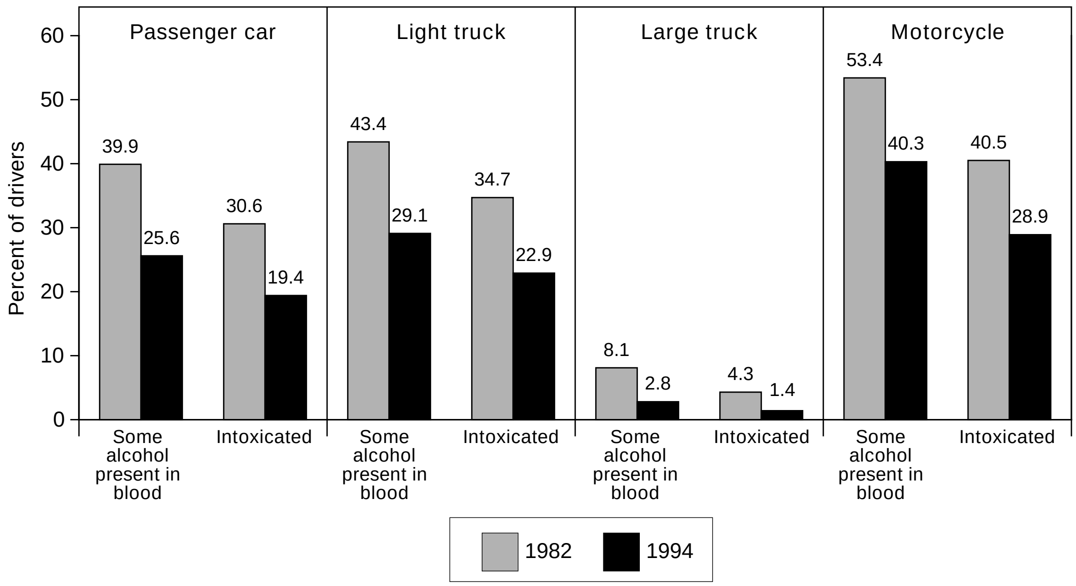
► Alcohol and Drugs

In 1994, 16,589 people were killed in alcohol-related highway accidents. (USDOT BTS 1996, 125) These accidents accounted for 41 percent of the people killed in highway accidents and 18 percent of people killed in accidents of all kinds. Alcohol was also involved in crashes resulting in 297,000 injuries. (USDOT NHTSA 1995c) Over the past five years, many states have reported that from one-quarter to one-third of drivers arrested each year for driving while intoxicated are repeat offenders. For drivers involved in fatal crashes, rates of alcohol involvement are highest for people aged 21 to 24, followed by people aged 25 to 34.

Progress has been made in curtailing drunk driving. From 1982 to 1994, the percentage of alcohol-related fatalities declined from 57 percent to 41 percent of crash fatalities. Moreover, a lower percentage of drivers involved in fatal crashes were intoxicated or had been drinking (see figure 3-3). For example, the intoxication rate for drivers of large trucks involved in fatal crashes fell from 4.3 percent to 1.4 percent in this period. Alcohol use for motorcyclists continues to be stubbornly high; some alcohol was present in the blood of 40.3 percent of the motorcycle operators involved in fatal crashes in 1994, and 28.9 percent were intoxicated. (USDOT NHTSA 1995c) Despite progress, drunk driving and its tragic consequences remain at unacceptable levels.

Several factors have reduced alcohol-related fatalities: deterrence strategies, raising the legal drinking age to 21, changes in societal patterns of alcohol consumption, and increased public

FIGURE 3-3: DRIVERS IN FATAL CRASHES BY LEVEL OF BLOOD ALCOHOL CONCENTRATION AND VEHICLE TYPE, 1982 AND 1994



NOTE: The National Highway Traffic Safety Administration considers police-reported fatal traffic crashes as alcohol-related if either a driver or a nonmotorist had a blood alcohol concentration (BAC) of at least 0.01 grams per deciliter. Persons with a BAC of 0.10 grams per deciliter are considered intoxicated in most states.

SOURCE: U.S. Department of Transportation, National Highway Traffic Safety Administration, *Traffic Safety Facts 1994,* DOT-HS-808-292 (Washington, DC: August 1995), table 17, p. 35.

awareness. Sobriety checkpoints and administrative license revocation (i.e., immediate loss of license following arrest) are two proven deterrents. Research shows that communities using sobriety checkpoints experience significant decreases in alcohol-related traffic crashes. (Ross 1992) The effectiveness of sobriety checkpoints, however, has been demonstrated only in the short run, because most programs were either new when they were evaluated or were designed as short-term programs. Administrative license revocation has been found to reduce fatal crashes by 7 to 9 percent. (Stewart and Voas 1994) Currently, 33 states and the District of Columbia have administrative license revocation laws.

Another way to deter drunk driving is to lower the legal blood alcohol concentration (BAC) limit. By 1994, 11 states had reduced the BAC limit from 0.10 grams per deciliter (g/dl), which is standard in most states, to 0.08 g/dl; and most states also had set an even lower BAC legal limit for drivers under 21 years of age. In California, administrative license revocation combined with a BAC limit of 0.08 has contributed to a 12 percent reduction in alcohol-related fatalities. (Stewart and Voas 1994)

As of 1994, all 50 states and the District of Columbia had set 21 as the legal drinking age, a step that has reduced alcohol-related traffic fatalities among young people. Nearly 14,000 lives have been saved since 1975 because of the increase in the legal drinking age. (USDOT NHTSA 1995a) In 1982, 31 percent of drivers ages 16 to 20 who were involved in fatal crashes had a BAC of 0.10 g/dl or higher. By 1994, that figure had dropped to 14 percent. A comparison among states found that those with lower BAC limits experienced a 42 percent decrease in teenage fatalities, while those without the lower limit had a 29 percent decrease over the same period. (Hingson 1992)

Many pedestrians who are killed in accidents with motor vehicles are intoxicated. In 1994, alcohol was present in the blood of over 40 percent of the pedestrians killed, ages 14 and older, and about one-third had BAC levels of 0.10 g/dl or more. By comparison, about 19 percent of motor vehicle drivers in crashes involving a pedestrian fatality had some alcohol in their blood. (USDOT NHTSA 1995c) Although the vast majority of alcohol- and other drug-related accident fatalities occur on highways, other transportation modes are not immune. Still, there has been progress in reducing the number of alcohol-related crashes for these modes.

The reduction in alcohol- and other drug-related crashes in the transportation workplace is largely attributable to drug- and alcohol-testing programs. Early estimates of the rate of alcohol and drug abuse ranged from 10 to 20 percent of the transportation workforce. Since the testing programs began in December 1989, the percentage of operators testing positive in the aviation and railroad industries has dropped to 3 percent. (Smith 1993)

▶ Human Fatigue

Human fatigue has long been recognized as a contributing factor in transportation accidents. The three-watch system was mandated in the maritime sector some 80 years ago, and hours-of-service (HOS) requirements in commercial trucking date back to 1939. Only recently, however, has human fatigue been recognized as a major problem in personal transportation.

Historically, fatigue was thought to be directly related to the amount of time behind the wheel. The HOS regulations established in the motor vehicle industry in 1939 were written from this viewpoint. Recent scientific evidence clearly shows, however, that two major physiological phenomena create fatigue: sleep loss and disruption in circadian rhythm, the body's internal 24-hour clock.

In transportation safety, human fatigue refers to the mental or cognitive fatigue of operators in any part of the transportation system. Unlike alcohol and drugs, which can be detected by tests, cognitive fatigue leaves no clear chemical or physiological evidence.

In general, fatigue increases the variability in operator performance, making it less reliable. It also increases cognitive errors, false responses, recall errors, the time to do a task, and reaction times.

Four main factors are usually assessed in accident investigations to determine whether fatigue played a role: 1) acute sleep loss or cumulative sleep debt, 2) length of time awake prior to the accident, 3) time of day of the accident (related to the body's circadian rhythm), and 4) existence of a sleep disorder such as chronic insomnia or sleep apnea. (NTSB and NASA Ames Research Center 1995)

Modal Comparisons of Human Fatigue

Each mode of transportation has examples of accidents attributed to human fatigue. One example was the grounding of the Exxon *Valdez* in Prince William Sound in 1989. Fatigue also was seen as the probable cause of the crash of American International Airways Flight 808 at the U.S. Naval Air Station at Guantanamo Bay, Cuba, in 1993. In the 24 hours prior to the accident, the flight's captain had only one-half hour of sleep. (NTSB 1994a)

The fatigue problem in transportation safety is difficult to assess, and therefore the size of the problem may be underestimated. This is particularly true of highway accidents for a number of reasons. First, the reporting practice for citing driver fatigue/drowsiness varies from state to state. Second, there are no tests that can provide firm evidence on which to base a police finding. Third, both police officers and drivers may not be aware of the role drowsiness or fatigue played in the crash, because it may be subtle and difficult to detect.

Based on National Highway Traffic Safety Administration (NHTSA) analysis, driver fatigue or drowsiness is cited on the police report for between 79,000 to 103,000 highway crashes each year (about 1.2 to 1.6 percent of the total highway crashes). (Knipling and Wang 1995) These crashes account for about 3.6 percent of all fatal highway crashes. Other studies place the incidence rate of drowsy-driver crashes between 1 and 4 percent. (Knipling and Wang 1994)

NHTSA's analysis also showed that gender and age are important in drowsiness/fatigue-related crashes. Male drivers are twice as likely to be involved in drowsiness/fatigue-related crashes than female drivers, on a per vehicle-mile basis. Drivers younger than 30 years of age are four times more likely to be involved in drowsiness/fatigue-related crashes than those older than 30. (Knipling and Wang 1994) Time of day is also important. Drowsiness/fatigue-related crashes are most frequent in the early morning and early afternoon.

Drivers of passenger vehicles (cars and light trucks) accounted for 96 percent of drowsy-driver crashes according to NHTSA crash data for 1989 to 1993. Drivers of combination trucks (tractor trailers) accounted for 3.3 percent. Although passenger vehicles comprise the vast majority of drowsy-driver crashes, fatigue/drowsiness is a problem for many combination truck drivers. (Knipling and Wang 1994) Although police reports indicate that combination trucks have a lower rate of involvement in fatigue-related crashes on a vmt basis than passenger vehicles, they are driven, on average, over five times as many miles per year. Hence, their exposure level is high. Drowsy-driver crashes involving combination trucks generally result in more severe injuries and property damage. Moreover, crashes involving combination trucks cause more severe injuries to people outside the truck, such as pedestrians or occupants of other vehicles, than crashes involving only passenger vehicles. Thirty-seven percent of the fatalities and 20 percent of the injuries associated with drowsy-truck-driver crashes occurred to people outside the truck. Comparable percentages for passenger vehicles were 12 percent of the fatalities and 13 percent of the injuries. For all combination truck crashes, 87 percent of the fatalities and 75 percent of the injuries occurred to people outside the truck. (Knipling and Wang 1994)

The National Transportation Safety Board (NTSB) recently evaluated the role of fatigue in 107 single-vehicle heavy-truck accidents in which the driver survived. The study's purpose was to examine fatigue characteristics, not to determine the statistical incidence of fatigue; NTSB examined both fatigue- and nonfatigue-related accidents. Through interviews with drivers and review of log books, NTSB sought to reconstruct the duty/sleep patterns of the drivers in both groups for the 96 hours preceding the accidents. The review concluded that, among the cases, the most critical factors distinguishing the fatigue-related accidents were the duration of the most recent sleep period, the amount of sleep in the past 24 hours, and whether the driver had split the required eight hours of sleep into segments. (NTSB 1995) The NTSB study reported that drivers in these fatigue-related accidents not only had 25 percent less sleep in the 24-hour period prior to the accident than drivers in non-fatigue-related accidents, but had 30 percent less sleep during the last sleep period. A higher proportion of the drivers in these fatigue-related crashes also had schedule irregularities or inverted duty/sleep periods before their accidents. Furthermore, driving at night with a sleep deficit is far more dangerous than simply driving at night. (NTSB 1995)

Technological innovation and economic competition have reduced the size of ship crews in the maritime industry. Because the safety of modern ships is more dependent on the ships' crews than on any other factor, merchant vessel casualties are often the result of human error. Because of a lack of reliable data and the difficulty in identifying the role of fatigue in marine incidents, the impact of reduced manning on marine safety has yet to be quantified. Still, some recent research suggests that the current three-watch system, in conjunction with reductions in manpower, might intensify the fatigue problem aboard merchant vessels. (Williams and Helmick 1995)

Measures To Combat Fatigue

Fatigue as a cause of transportation accidents can be addressed through: 1) education and training, 2) HOS limits, 3) scheduling, and 4) countermeasures and technology. Education and training can play a critical role in efforts to combat the effects of human fatigue in transportation. It has been widely recognized that the amount of sleep needed varies from person to person, that operators may not be aware of, or recognize, fatigue symptoms, and that regulations and laws alone cannot guarantee that drivers and other operators get enough sleep. Transportation Secretary Federico Peña underscored the importance of education and training: "If it's human behavior we must change, then we need to educate and not just regulate." (Peña 1995)

In commercial transportation, HOS and scheduling are key to understanding the fatigue problem. Current HOS rules require truck drivers to be off duty for at least eight consecutive hours after either 10 hours of driving and/or spending 15 hours on duty. The eight-hour off-duty requirement has been criticized by NTSB as not providing enough time for drivers to get adequate rest while also taking time for travel, eating, personal hygiene, and recreation. The Federal Highway Administration is conducting research to provide a technically sound basis for evaluating HOS regulations.

Current aviation regulations require a rest period of at least 10 hours for a pilot scheduled to fly an eight- to nine-hour flight. To provide scheduling flexibility under unexpected circumstances, however, the regulations allow flight crews to operate with a shorter rest period as long as they subsequently get compensatory rest. According to NTSB, some airlines not only apply these provisions in unexpected circumstances, as originally intended, but also routinely use them when scheduling flight crews. (NTSB 1995) Thus, NTSB recommended that airlines be made aware of, and comply with, the *original intent* of the rest regulations.

Finally, research suggests that other countermeasures may be effective in combating fatigue. Examples include bright lights, strategic napping, in-vehicle fitness-to-drive devices, and rumble strips on the shoulders of highways. Vehicle-based driver drowsiness detection and warning systems are also the subject of research. The cost-effectiveness of some of these countermeasures has yet to be proven.

The U.S. Department of Transportation (DOT) has assumed leadership in the effort to prevent fatigue-related transportation accidents. (USDOT 1995) Because the quantity and quality of sleep are critical to avoiding fatigue, DOT conducts some research on sleep. Much of DOT's activity, however, concentrates on vehicles and environments: control centers, airplane cockpits, truck cabs, locomotive cabs, ship bridges, and driver compartments of cars and buses.

Occupant Protection Devices

Accidents and injuries can be reduced through various devices that protect the occupant. Seat belts, when properly worn, greatly reduce the number and severity of injuries in highway accidents. According to NHTSA, lap/shoulder belts reduce the fatality risk for front-seat passengers by 45 percent and are slightly more effective in preventing moderate to critical injuries. In 1994, seat belts saved an estimated 9,175 lives of all occupants. (USDOT NHTSA n.d.a) As of 1994, all but three states had a mandatory seat belt use law, and observational survey data showed that 67 percent of all passenger car occupants wore their seat belts. (USDOT NHTSA n.d.a) It is, however, becoming harder to increase the rate of seat belt use.

In 1994, airbags saved the lives of an estimated 374 people. The most effective protection is provided when lap/shoulder belts are used in vehicles equipped with airbags. (USDOT NHTSA n.d.a) Child safety seats placed in the correct position can reduce the risk of fatal injury by 69 percent for infants and by 47 percent for toddlers. (USDOT NHTSA n.d.a) Motorcycle helmets saved an estimated 527 lives in 1994, and an additional 294 lives might have been saved if all motorcyclists had worn helmets. (USDOT NHTSA n.d.b)

Despite significant progress in vehicle safety standards and occupant protection devices, there is still much work to be done. For example, the aging of the U.S. population presents challenges. The design of traffic control devices is often based on performance measures of younger drivers. Likewise, vehicle designers often overlook the needs of older drivers, and driver licensing programs often do not adequately address problems faced by older drivers.

Mode-Specific Safety Issues

► Commuter Airline Safety

The commuter airline industry has grown dramatically and changed significantly over the past 15 years. From 1980 to 1993, the number of passengers flying in aircraft operated by regional airlines (which account for most commuter service) increased from 15 million to over 52 million; the number of their aircraft grew from 1,339 to 2,208. (NTSB 1994b) Because of growing demand, regional airlines have added larger, more sophisticated airplanes to their fleets. As a result, the average seating capacity increased from just under 14 seats per airplane in 1980 to 23 seats in 1993. Today, nearly 70 percent of U.S. communities with scheduled air service depend on regional or commuter airlines.

As commuter airlines moved into markets once served by major airlines or began to serve new markets, they often entered into *codesharing* arrangements with a major airline. Typically, the commuter airline uses a similar designator code in the airline reservation systems. It also paints its aircraft with a color scheme and does business under a company name that closely resembles that of the major airline. In 1993, 36 of the 50 largest commuter airlines had a codesharing arrangement with at least one major airline.

Although such associations have made many travelers less aware of the distinction between a major airline and its codesharing partner, there have been significant regulatory and operational differences between the major and commuter carriers. For example, the codesharing arrangement does not always mean that the major airline directly oversees its codesharing partner's flight operations, maintenance, or safety.

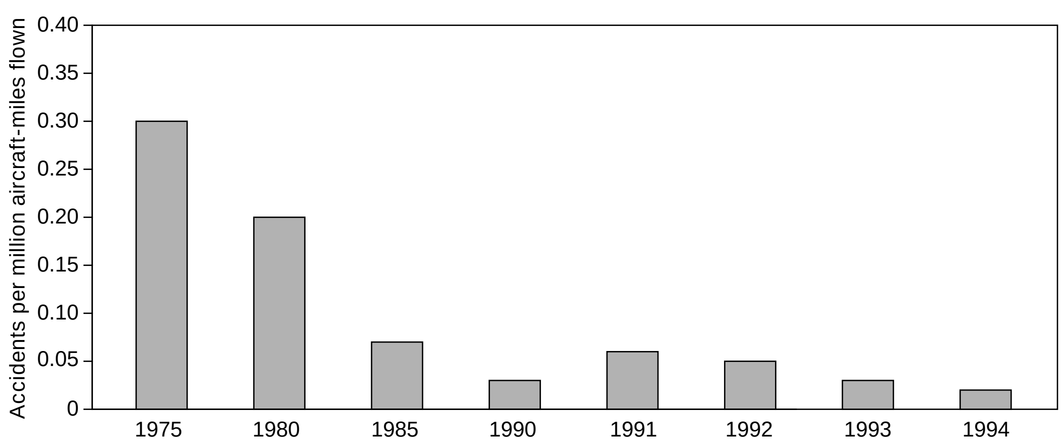
In the past, the regulations applied to commuter aircraft with 30 or fewer seats (Title 14 *Code of Federal Regulations*, Part 135) were less stringent than those applied to aircraft with more seats (Title 14 *Code of Federal Regulations,* Part 121). Different requirements existed for flight operations, pilot training, flight-time limits, operational control, and maintenance personnel. With the rapid growth in passenger traffic and changes in the operational characteristics of commuter airlines, the regulations had not kept pace with many of the changes in the industry. (NTSB 1994b)

Even so, the joint efforts of government and industry during the past 15 years have brought about significant safety improvements in the commuter airline industry. The accident rate per million aircraft-miles of service conducted under Part 135 has declined significantly since 1980 (see figure 3-4). Yet, accident rates for these aircraft continue to be higher than for larger commercial aircraft.

In its recent study of commuter airline safety, NTSB found that many commuter airlines had taken advantage of regulatory provisions allowing them to establish flight crew schedules, under unexpected circumstances, with reduced rest periods. Many pilots in the survey admitted flying while fatigued and attributed their fatigue to such factors as length of duty day and reduced rest periods. About one-third of the pilots interviewed in NTSB's study said that more formal crew resource management training and operating experience would be beneficial. Overall, the study found commuter airline regulations inadequate to make passengers as safe as those flying on major airlines. (NTSB 1994b)

On December 14, 1995, Transportation Secretary Federico Peña and Federal Aviation Administrator David R. Hinson announced issuance of tougher safety rules for commuter airlines. Under the new rules, all scheduled passenger service using airplanes with 10 or more seats will be operated under the same safety standards as larger planes, with a few "common sense" exceptions. (*FAA News* 1995)

FIGURE 3-4: ACCIDENT RATES FOR U.S. COMMUTER AIRLINES, 1975–94



NOTE: Commuter airlines refer to all scheduled service conducted under 14 CFR 135.

SOURCE: National Transportation Safety Board, *Aviation Accident Statistics,* annual issues, as compiled and cited in U.S. Department of Transportation, Bureau of Transportation Statistics, *National Transportation Statistics 1996* (Washington, DC: November 1995), table 36.

Accidents at Highway-Railroad Crossings

Although rail is one of the safest modes of transportation, accidents at highway-railroad crossings remain a significant problem. About half of all rail-related fatalities are the result of collisions between trains and vehicles at railroad crossings. In 1994, about 5,000 such collisions occurred, killing 615 people and injuring 1,961. (USDOT BTS 1996)

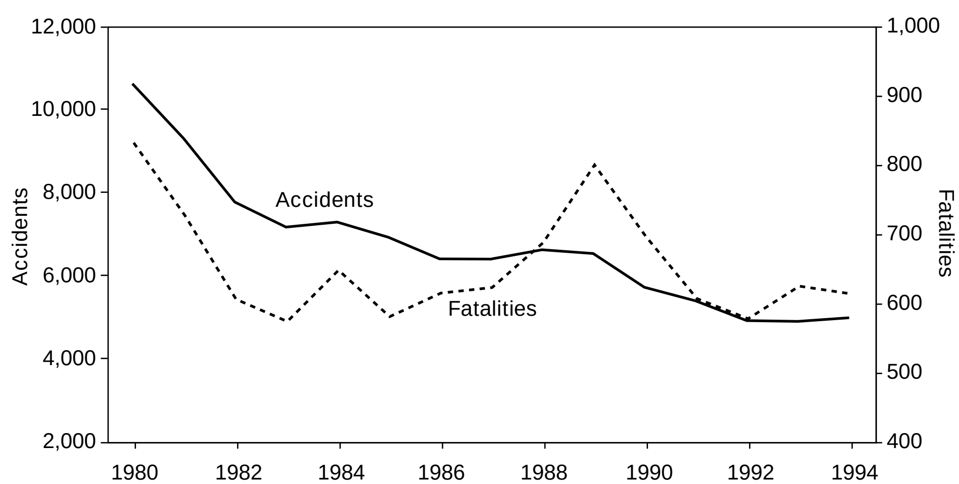
Government and the railroad industry have cooperated to improve railroad crossing safety through the Rail-Highway Crossing Program begun in 1974. Since 1980, the number of accidents at public railroad crossings has been more than cut in half. Fatalities, however, have risen in some years and declined in others (see figure 3-5).

The Federal Railroad Administration (FRA) has developed a surrogate accident exposure index based on train-miles traveled and vehicle-miles traveled. Based on this index, FRA estimated that accident exposure at railroad crossings rose by 39 percent between 1985 and 1993, adversely affecting safety at railroad crossings. (USGAO 1995)

From 1975 to 1994, the number of public crossings decreased by 24 percent. The level of warning provided at the 166,000 public crossings that remained in 1994 varies widely, from no visible warning devices to several kinds of active devices. Active devices (e.g., automatic flashing lights and lights with gates) are more effective than passive devices (e.g., crossbucks and stop signs). Even so, crossings pose a major safety challenge because of growing rail traffic and higher speed passenger and freight rail operations.

When it is not practical to close a crossing, states can use alternatives such as new technologies, public education, and law enforcement. Traditional technologies such as lights and gates are not foolproof. New technologies, such as those that prevent vehicles from entering the crossing when trains approach, may be effective, but they are more costly. Thus, they are reserved for more dangerous crossings.

FIGURE 3-5: ACCIDENTS AND FATALITIES AT RAIL-HIGHWAY GRADE CROSSINGS, 1980–94



SOURCES: Various sources, as compiled and cited in U.S. Department of Transportation, Bureau of Transportation Statistics, *National Transportation Statistics Annual Report, Historical Compendium, 1960–1992* (Washington, DC: September 1993); and *National Transportation Statistics 1996* (Washington, DC: November 1995).

Drivers who ignore warning signs are a major cause of railroad crossing accidents and fatalities. Law enforcement and educational programs have modified motorist behavior in many states. For example, Ohio, which has comprehensive law enforcement and educational programs, experienced a reduction in accidents at crossings with active warning devices—from 377 in 1978 to 93 in 1993. (USDOT BTS 1996)

Under its Rail-Highway Crossing Safety Action Plan, DOT aims to reduce railroad crossing accidents and fatalities by 50 percent from 1994 to 2004. A combination of strategies will be needed to effect this large reduction. Thus, DOT plans to provide states with financial and technical assistance to remove unnecessary crossings and to mount public education campaigns. Joined by the industry, Operation Lifesaver, and the Brotherhood of Locomotive Engineers, DOT is promoting *Always Expect a Train*, a national multimedia campaign to educate people about the dangers of ignoring warning signs at railroad crossings. In addition, DOT seeks to eliminate half of the 4,500 highway-rail crossings on the National Highway System and to continue to sponsor research on innovative technologies.

Safety Technologies

Development of crash avoidance systems (CASs) is an area of intelligent transportation systems (ITS) research. An essential step in the development of these systems is to understand both the magnitude and causes of crashes. DOT is using data on different kinds of crashes to identify opportunities for the application of advanced technologies to crash avoidance. (USDOT FHWA 1994, USDOT NHTSA 1995b)

Three kinds of crashes (the rear-end collision, intersection crashes, and single vehicles going off roads) accounted for three-quarters of crashes in 1993. (USDOT NHTSA 1995b) (see table 3-8). Three other major crash types (those involving lane changes or merges, backing, and opposite-direction collisions) total only about 10 percent of crashes, but still each account for between 169,000 and 237,000 crashes per year. Drivers were a contributing factor in 89 percent of these crashes. Driver recognition and decision errors predominated, followed by erratic actions and physiological impairment.

Several collision avoidance methods are under development. *Advisory systems*, which range in sophistication from in-vehicle warning indicators to traffic control systems and road signs, caution a driver about potential hazards.

Table 3-8: Number of Crashes by Main Crash Types

Accident type	Number of crashes
Rear-end	1,537,000
Rear-end, lead vehicle stationary	979,000
Rear-end, lead vehicle moving	558,000
Backing	177,000
Encroachment backing	82,000
Crossing path backing	95,000
Lane change/merge	237,000
Angle/sideswipe lane change/merge	226,000
Rear-end lane change/merge	11,000
Single-vehicle roadway departure	1,241,000
Intersection crossing path (ICP)	1,805,000
Signalized intersection straight crossing path	204,000
Unsignalized intersection straight crossing path	359,000
Left turn across path	405,000
Other ICP	837,000
Opposite direction	169,000
Other types of crashes	927,000
All crashes	6,093,000

SOURCE: U.S. Department of Transportation, National Highway Traffic Safety Administration, *Synthesis Report: Examination of Target Vehicular Crashes and Potential ITS Countermeasures,* prepared by Volpe National Transportation Systems Center, DOT-VNTSC-NHTSA-95-4 (Washington, DC: June 1995), table 2-1.

Driver warning systems alert the driver to a situation that requires immediate action to avoid a crash. *Control intervention systems* are triggered by an imminent collision in which driver action alone may be inadequate to avoid a crash.

There are challenges with each of these approaches that need to be addressed. Both advisory and warning systems must give the driver crucial information at critical times without becoming a nuisance or distraction. The tradeoffs between nuisance alarms and effective crash avoidance are not yet well understood. For example, repeated nuisance alarms in situations that do not pose a true crash threat could cause drivers to ignore warnings that should be taken seriously. Control intervention systems need to be designed so that adverse secondary safety consequences are minimized or eliminated. The systems need to be extremely reliable and readily acceptable to drivers.

Some research focuses on remedying *driving task errors* associated with particular kinds of crashes. Examples include headway detection systems, situation displays, in-vehicle signing, and lane position monitors. The effectiveness of these concepts is as yet unknown.

Many other ITS countermeasures are at various stages of research or development. Examples include driving vigilance monitors to alert drivers of drowsiness, intoxication, or other functional impairment, devices to monitor pavement conditions or status of vehicle components, and vision enhancement systems.

Although the potential of crash avoidance systems is promising, their effectiveness can only be evaluated through driving situations encountered in the real world. Understanding how drivers will respond to CAS countermeasures is central to evaluating their effectiveness. For example, it is possible that some drivers will erroneously believe that CAS protects them from all crashes, and will pay less attention to driving and take more risks. It is also important to understand how avoiding one crash might lead to another. For example, automatic emergency braking might avoid rear-ending a vehicle ahead, however, the maneuver might cause the braking vehicle to be rear-ended itself. (Tijerina 1995)

In sum, both positive and possible negative effects need to be taken into account in CAS design, implementation, and evaluation. Moreover, cost-effectiveness, hardware reliability, maintainability, and interoperability for cooperative systems needs to be considered in assessments of CASs. One of the greatest challenges facing the transportation system is to understand how technology—broadly defined, as well as specific technologies—can make transportation safer.

Data Needs

Inadequate data and inconsistent measures of accident risk across modes complicate efforts to formulate strategies to reduce transportation risks. Transportation safety data needs fall within four areas: 1) more uniform reporting of accidents throughout the nation, 2) more comprehensive data on environmental conditions and other contributing factors, 3) comprehensive and consistent measures of risk exposure, and 4) more thorough reporting of injuries.

Accident statistics across different data systems are difficult to compare because of inconsistent definitions and reporting criteria. For example, different states use different criteria to determine when police are required to report accidents involving only property damage. Most states use vehicle damage costs as the primary criterion. Damage thresholds vary significantly, however, ranging from $50 in Arkansas and the District of Columbia to $1,000 in Colorado. (O'Day 1993)

More comprehensive information on environmental conditions (e.g., weather, lighting, road conditions) and on other contributing factors is needed to better understand their roles in crashes.

The lack of accurate, comprehensive, and consistent measures of risk exposure hinder progress in understanding the relative importance of the various factors contributing to transportation crashes. Many different types of exposure measures (e.g., number of licensed drivers, vehicle-miles traveled, person-miles traveled, number of hours flown) are used to analyze accident statistics. There is disagreement, however, about which best measures crash risk. Furthermore, the available measures of risk exposure may differ from one mode to the next, making it difficult to compare risks among modes. For example, if vehicle-miles-traveled is the measure of risk exposure for highway crashes and the number of hours flown is the measure used for general aviation accidents, how will we compare safety trends between the two modes? Moreover, when data on risk exposure by vehicle type are broken down to take account of other considerations such as time of day and highway type, the data are not accurate enough for rigorous statistical analyses.

The underreporting of transportation injuries, along with inconsistencies in injury reporting, further complicates assessment of transportation safety. Using the Functional Capacity Index to quantify the reduction of a person's capacity to function following an injury, an estimated 1.3 million years of life are lost annually because of motor vehicle injuries, compared with 1.6 million years lost due to motor vehicle fatalities. (Evans 1991) This measure suggests the devastating consequences of injuries to society. The reporting of injuries, however, is less comprehensive and consistent than the reporting of fatalities. Reporting inconsistencies are reflected in a comparison of police-reported injuries from 23 states. For example, although all these states reported that they collect and automate data for *all* crashes with *any* injury, California reports that only 5 percent of its transportation injuries are incapacitating, while Illinois reports 24 percent. (Evans 1991) It would be useful to develop new training materials to promote consistent reporting of injuries across the nation.

Improvement in the data in these and other areas could contribute to a better understanding of transportation safety problems. Such understanding, in turn, could help in the development of strategies and countermeasures to reduce the frequency and severity of crashes. It also could help in establishing priorities in an era of limited resources.

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